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JCS52 U.S. PTO

**UTILITY PATENT  
APPLICATION TRANSMITTAL LETTER**

JCS51 U.S. PTD  
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06/10/99

Box: PATENT APPLICATION  
Honorable Commissioner of Patents and Trademarks  
Washington, DC. 20231

Sir:

Enclosed for filing is the utility patent application of Francine J. Prokoski for:  
**METHOD AND APPARATUS FOR ALIGNMENT, COMPARISON & IDENTIFICATION  
OF CHARACTERISTIC TOOL MARKS, INCLUDING BALLISTIC SIGNATURES**

Also enclosed are:

- ☒ [16] sheets of ☐ formal ☒ informal drawings;
- ☐ a claim for foreign priority under 35 U.S.C. §§ 119 and/or 365 in ☐ a separate document
- ☒ the declaration;
- ☐ a certified copy of the priority document;
- ☐ an Associate Power of Attorney;
- ☒ One verified statement claiming small entity status; and
- ☐ an Assignment document
- ☐ an Information Disclosure Statement.
- ☒ the Declaration of the inventors also is enclosed.


The fee has been calculated as follows:

| CLAIMS   |                     |              |        |                  |
|--|---------------------|--------------|--------|------------------|
|  | NUMBER<br>OF CLAIMS | EXTRA        | RATE   | FEE              |
| Basic Application Fee  |                     |              |        | \$ 690.00        |
| Total Claims   | 24                  | Minus 20 = 4 | @ \$20 | 80.00            |
| Independent Claims   | 12                  | Minus 3 = 9  | @ \$72 | 648.00           |
| If multiple dependent claims are presented add \$220.00  |                     |              |        | 0                |
| Total Application Fee  |                     |              |        | \$ 1418.00       |
| If verified statement claiming small entity status is enclosed, subtract 50% of<br>Total Application Fee |                     |              |        | \$ 709.00        |
| Add Assignment Recording Fee of \$40.00 if Assignment document is enclosed                               |                     |              |        | 0                |
| <b>TOTAL APPLICATION FEE DUE</b>   |                     |              |        | <b>\$ 709.00</b> |

- ☒ [X] A check in the amount of \$709.00 is enclosed.

The Commissioner is hereby requested to notify us of any fees under 37 C.F.R. §§ 1.16, 1.17, and 2.21 that may be required by this paper.

Respectfully submitted,

  
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Applicant of Patentee: Francine J. Prokoski  
Serial or Patent No.: \_\_\_\_\_  
Filed or Issued: \_\_\_\_\_

For: METHOD AND APPARATUS FOR ALIGNMENT, COMPARISON & IDENTIFICATION OF  
CHARACTERISTIC TOOL MARKS, INCLUDING BALLISTIC SIGNATURES

**VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS**  
**(37 C.F.R. §§ 1.9(F) AND 1.27 (B)) - INDEPENDENT INVENTOR**

As the below-named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 C.F.R. § 1.9(c) for purposes of paying reduced fees under Section 41(a) and 41(b) of Title 35, United States Code, to the Patent and Trademark Office with regard to the invention entitled METHOD AND APPARATUS FOR ALIGNMENT, COMPARISON & IDENTIFICATION OF CHARACTERISTIC TOOL MARKS, INCLUDING BALLISTIC SIGNATURES

☒ the specification filed herewith  
☐ Application Serial No. \_\_\_\_\_ filed \_\_\_\_\_  
☐ Patent No. \_\_\_\_\_, issued \_\_\_\_\_.

I have not assigned, granted, conveyed, or licensed and am under no obligation under contract or law to assign, grant, convey, or license any rights in the invention either to any person who could not be classified as an independent inventor under 37 C.F.R. § 1.9(c) if that person had made the invention, or to any concern that would not qualify as either a small business concern under 37 C.F.R. § 1.9(d) or a nonprofit organization under 37 C.F.R. § 1.9(a).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

☒ no such person, concern, or organization  
☐ persons, concerns, or organizations listed below\*

\*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 C.F.R. § 1.27.)

FULL NAME NONE  
ADDRESS \_\_\_\_\_

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earlier of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 C.F.R. § 1.28(b).)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code; and that such willful false statements may jeopardize the validity of the application, and patent issuing thereon, or any patent to which this verified statement is directed.

Name Francine J. Prokoski

Signature

Francine J. Prokoski

Date

8 June 1999

660150-2-99

**APPLICATION FOR  
UNITED STATES LETTERS PATENT**

**By**

**FRANCINE J. PROKOSKI  
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Fairfax Station, VA 22039-7025**

**For**

**METHOD AND APPARATUS FOR ALIGNMENT, COMPARISON & IDENTIFICATION  
OF CHARACTERISTIC TOOL MARKS, INCLUDING BALLISTIC SIGNATURES**

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defects, or hand finishing done in high quality weapons. Breech face marks can be compared just as can firing pin marks, either by firing a test round or by examining the weapon when the weapon is available, or by comparing corresponding marks on two bullets or casings which are suspected of coming from the same weapon. If the same weapon is used to fire the same type ammunition at the same type target from the same distance, comparable patterns will be produced on the bullet and casing. If the ammunition is changed, the patterns will be somewhat different.

Tool marks can be also transferred to the casing by the extractor and ejector of semiautomatics and automatics. Such marks include indentations and striations. The ejector is likely to gouge the casing. The extractor pulls the casing from the breech, imposing perhaps additional striations and indents before it hits the ejector.

Class characteristic marks vary with calibre, load, material used for the bullet or shot, bullet weight, its impact behavior, material used for the casing, and identification stamped into the bullet and casing. Intentional marks on ammunition include information stamped on the face of the bullet casing during molding of the shells. Some casings and bullets also have an indented ring or rings around the circumference called a canellure. These are smeared with grease or wax as sealer, making the bullet water-resistant and providing some lubrication as it is forced through the barrel. The canellures on the casing are imprinted within a quarter inch from the top after the bullet is inserted. This crimp acts to seal the round and hold the bullet in the casing. Canellures may contain imprint information unique to the manufacturer and perhaps to a particular crimping tool.

Ammunition for handguns, rifles and shotguns all contain an outer casing or shell, a primer device to ignite, a fast burning material which is a form of nitrocellulose, and a projectile to fly out the barrel. Ammunition that travels through a particular gun receives scratches from the barrel of the gun, indentation from the firing pin, and perhaps other marks from the breech face and ejector, in addition to fingerprints. The hand of the person firing the weapon receives a spray of gun residue which may be characteristic of a particular type of weapon and ammunition. The target receives some degree of blowback from the weapon and the target itself, plus perhaps fragments of any materials through which the bullet passed.

Markings on ballistic items which are of interest to forensics include:

- Fingerprints on the weapon, projectile, or casing.
- Other debris and material on the weapon, projectile, or casing.

- Characteristics on the projectile or casing associated with the particular brand and type of ammunition used.
- Characteristics on the projectile or casing associated with the particular weapon used. These are called tool marks.

During manufacture, grooves are cut into the hard steel of pistol and rifle barrels, spiraling from the chamber to the muzzle. They cause the bullet to spin, which results in the bullet having a cleaner trajectory and the weapon having more accurate targeting. The raised areas between grooves are called lands. Bullets are intended to be fired in a particular calibre weapon. Nitrocellulose burns to produce an expanding gas, which drives the bullet through the barrel. The resulting heat causes the bullet to expand and softens its surface. Lead bullets are particularly prone to softening. The bullet is blown out of the shell casing and forced into the barrel, which is tighter. As a result, the lands are cut into the moving bullet and the surface is squeezed into the grooves. The high points of the barrel cause scratches in the bullet, which are referred to as striation evidence. The material used in the bullet determines the depth of the striations.

The number, width and depth of the grooves and the angle and direction (right or left) of their spiral are determined by the manufacturer. Lands and grooves together are called rifling. Rifling marks are transferred to the bullet as it is forced through the barrel. Some marks indicate the class of weapon used, while others indicate the particular gun or barrel used in the case of weapons with interchangeable barrels.

Most weapons other than Colt use a right twist. The number of lands or grooves typically is four to seven. The width varies depending on the number and the calibre. The degree of twist is measured by the distance traveled during one complete rotation of the bullet. A typical Colt handgun can be described as a left twist, six lands, 1/12. Most handgun barrels are shorter than 12 inches. Therefore, the energy transferred to spinning the bullet is not as great as in a rifle.

When the ammunition used is smaller than that designed to be used in a weapon, the result is loss of energy and penetration. In addition, since the bullet is loose within the barrel, inconsistent striations will occur on various bullets fired through the weapon.

Maintenance done on a weapon can alter the characteristics imposed on its ammunition. Use, cleaning, corrosion, and intentional damage to a barrel can all affect the ability to match ammunition used in it over time. Rust or corrosion will alter fine details. Some semiautomatics and automatics have interchangeable barrels. After exiting the barrel, the bullet may receive additional distortions as it passes

1 through various materials. The result may be to destroy the forensic value of the bullet, or may be just to  
2 require further analysis.

3 The shell casing receives marking from the firing pin hitting the primer, from the back pressure of  
4 the gas expansion slamming the casing against the breech face of the firing pin housing which may have  
5 marks or defects which transfer onto the primer and/or casing. These marks may be a result of  
6 manufacturing defects, or result from the hand finishing done in high quality weapons. Breech face marks  
7 can be compared just as can firing pin marks, either by firing a test round or by examining the weapon when  
8 the weapon is available, or by comparing corresponding marks on two bullets or casings which are  
9 suspected of coming from the same weapon. If the same weapon is used to fire the same type ammunition  
10 at the same type target from the same distance, comparable patterns will be produced on the bullet and  
11 casing. If the ammunition is changed, the patterns will be different.

12 Shell casings are ejected immediately from automatic and semis, and so fall close to where the  
13 firing occurs. Revolvers retain the casings until intentionally ejected, and so are often carried away from the  
14 crime scene. Tool marks can be transferred to the casing by the extractor and ejector of semis and  
15 automatics. Such marks include indentations and striations. The ejector is likely to gouge the casing. The  
16 extractor pulls the casing from the breech, imposing perhaps additional striations and indents before it hits  
17 the ejector.

18 Class characteristic marks vary with calibre, load, material used for the bullet or shot, bullet weight,  
19 its impact behavior, material used for the casing, and identification stamped into the bullet and casing.  
20 Intentional marks on ammunition include information stamped on the face of the bullet casing during  
21 molding of the shells. Some casings and bullets, particularly lead, also have an indented ring or multiple  
22 rings around the circumference called a canellure. These are smeared with grease or wax when first  
23 inserted into the casing. The material acts as sealer, making the bullet water-resistant and providing some  
24 lubrication as it is forced through the barrel. The canellures on the casing are imprinted within a quarter  
25 inch from the top after the bullet is inserted. This crimp acts to further seal the round and hold the bullet in  
26 the casing. Canellures may contain imprint information unique to the manufacturer and perhaps even to a  
27 particular crimping tool.

28 Types of ammunition are distinguished by their size. All handguns are designated by calibre in  
29 either inches or millimeters. For example a .22 calibre is 22/100 inch. The length of the shell varies to  
30 increase the capacity of gunpowder. A .22 may be short, long or long rifle, plus a magnum load. All

1 magnum loads contain more gunpowder and may propel a heavier bullet. Magnum weapons are always  
2 designed to be heavier to contain the increased force. A magnum weapon can chamber a regular load, but  
3 a regular weapon cannot chamber a magnum round.

4 Some .22 handguns and rifles can chamber only the short, some can chamber short and long, and  
5 others can handle all three. The .22 short and long have the same weight bullet, while the long has more  
6 powder. The long rifle has more powder still and a heavier bullet but still is not considered a magnum load.  
7 All .22 rounds of these types are rim fire primers, rather than center core primers. Some high-powered  
8 rifles can proper .22 calibre bullets with center core primers, but the shell casings are huge relative to this  
9 group.

10 The .25 calibre pistol purse gun is designed to be easily concealed. There are .32 calibre revolvers  
11 and semiautomatics. The .32 calibre rim fire primers were used in early revolvers, but all modern rounds  
12 are center core primers.

13 There are two types of ammunition for .38 calibre (.357) revolvers; the .38 S&W and the .38  
14 Special. The .38 Smith and Wesson is a shorter shell with smaller load. It has been superceded by the  
15 more powerful .38 Special, designed for law enforcement use. The maximum stopping power for the .38  
16 calibre became available when the .357 magnum was marketed. The weapon fires a heavier bullet, with  
17 longer casing that contains additional gunpowder. However, when firing a solid lead bullet, the weapon  
18 proved a hazard to unintended secondary targets, because the penetrating power was too great.

19 For police use, a combination of stopping power and safety are desired. Several .38 calibre bullets  
20 are designed to impact only the first target, transferring all the kinetic energy to it. Hollow point bullets were  
21 designed for this purpose. A hollow point is a soft lead bullet encased in a thin steel jacket. The point is  
22 actually an opening with thin lead walls. On impact the wall flare out. The final shape of the bullet, in the  
23 side view is similar to a mushroom. Hence the term "mushrooming" is applied. Hollow points don't  
24 necessarily mushroom every time, and can still harm secondary targets, such as by passing through soft  
25 tissue of the target and injuring someone behind.

26 Glasser bullets were developed with a prefragmented round constructed of a thin metal skin packed  
27 with very small lead particles suspended in liquid Teflon. The bullet's weight is equal to that of a solid lead  
28 bullet, resulting in equivalent kinetic energy. When the Glasser hits any resisting surface, the thin walls  
29 flatten out, distributing the tiny lead particles over a wide area. A bullet hitting a human or animal penetrates  
30 and opens up, transferring all its energy to the inside of the target, having an elephant gun effect. The

1 Glasser offered improved safety since all energy was expended when the bullet hit something. Errant shots  
2 striking pavement would not ricochet. Bullets hitting a house would not penetrate walls. Other  
3 manufacturers also offer prefragmented bullets.

4 Shotgun shells are different from handgun and rifle ammunition. Although solid metal casings have  
5 been used, they are now mostly replaced by a combination casing with a metal face and base connected to  
6 a plastic or waxed cardboard cylinder. Shotgun shells are available in gauges 10, 12, 14, 16, 20, and 410.  
7 The cylinder is crimped shut, sealing in the projectiles, shot and other materials with the gunpowder. The  
8 face contains manufacturer's information and markings and houses a center core primer. The actual  
9 projectiles vary. The shot, which was traditionally lead, is gradually being replaced by steel balls. Lead shot  
10 has been cited by environmentalists as causing lead contamination in waterways.

#### 11 12 **CURRENT TECHNOLOGY FOR TOOL MARK IDENTIFICATION**

13 Firearms examiners can study the shell casings collected at one crime scene and determine the  
14 number of different weapons involved. They can compare the casing to those from other sources. They  
15 can also compare bullets to determine the possibility they came from the same weapon, and they can  
16 analyze weapons for characteristics which might match bullets and casing fired from it. Current  
17 examinations of firearms, bullets and casings use low-powered stereo binocular microscopes combined  
18 with high-energy illumination. The systems incorporate computers to assist in finding likely matches  
19 between a new casing or bullet and databases of ones previously collected, selecting potential matching  
20 items. Although somewhat automated, current techniques are still labor intensive, acting only to select likely  
21 matching items for manual review by a ballistics expert. The FBI and the ATF have each established a  
22 network of computerized systems to support the identification of guns, bullets, and casings; allowing  
23 member labs to share databases.

24 The Drug Fire program started by the FBI in the 1990's has established a network of computers in  
25 more than 40 forensic labs that exchange breech face striation information. Each member agency is  
26 responsible for classifying all its cases, and placing the information in computer. Any member agency can  
27 then compare evidence from its case to all other cases in the system. A second system, Bulletproof  
28 developed for the ATF, records striations on the bullet while the casings are categorized by a system called  
29 Brass Catcher. The national scope of these two programs is intended to assist in investigations of drug-  
30 related gangs with national networks.

Baldur (5,390,108) presents a computer-automated bullet analysis apparatus. A microscope obtains and amplifies optical signals representative of the characteristics of the surfaces, and the optical signals are converted first to electrical signals and then to coded digital representations. The coded representations are stored in memory and are matched against one another to see if there is a match between the bullets. The ATF system is based upon that apparatus.

Land marks of 45 calibre bullets are normally photographed at 10X magnification and then enlarged to 4X, with a total enlarged ratio of 40X. 22 calibre long rifle bullets are commonly photographed at 20X, resulting in a total enlarged ratio of 80X. The reproducibility of land marks is better than for groove marks, especially for jacketed bullets. The width of groove marks is very wide compared to land marks in some cases; such as with 45 calibre bullets fired from an M1911A1 semi-automatic pistol. Imaging multiple groove marks at one time is difficult due to the need to focus at different depths.

Examiners compare the contour of the bullet surfaces using a comparison microscope. Not all of the bore surface characteristics will be reproducibly transferred even on consecutively fired bullets. In addition, there are always extraneous markings, which are not due to the gun bore surface, which an examiner must ignore.

Achieving proper illumination for detailed imaging is difficult with current matching systems. The metallic nature of the items causes glare and reflection to interfere with good imaging. Use of glancing light to highlight the relief structure interferes with distinguishing lands and grooves. Shadows create or mask features, and the depth of striations and indents cannot be determined. The automated analysis engines are computationally intensive and may be confused by manufacturing marks, shadow, glint, and focus. They may not distinguish between individual characteristics peculiar to the weapon, and manufacturing marks or incidental marks of no significance. The imagery and therefore the analysis is prone to variations due to differences in initial alignment, and to inconsistent lighting strength and direction from day to day and from lab to lab and technician to technician.

Current matching systems do not have the desired accuracy, speed, cost effectiveness, and ease of use. Due to the 3-D nature of the ballistic items, achieving proper illumination for detailed imaging is very difficult. The metallic nature of most of the items causes glare and reflection to interfere with good imaging. Use of glancing light to highlight the relief structure interferes with determining which marks are lands and which are grooves. Shadows create or mask features, and the depth of striations cannot be determined. Details of the firing pin indentation cannot be seen without causing significant glare and shadow.



1 The need is for a ballistics matching technology which is faster and cheaper than current techniques,  
2 which finds more correct matches with less manual intervention by a ballistics examiner, and which can  
3 exploit the current databases and enhance the performance of existing ballistics identification systems. The  
4 goal is to increase the capacity of the law enforcement community to identify increasing numbers of ballistic  
5 items, faster and with greater accuracy, and at minimum cost both in terms of manpower and system  
6 expenses.

7 The situation is analogous to that of fingerprint matching. As increasingly large databases are created,  
8 techniques are needed to partition those databases and to perform matches based upon feature  
9 characteristics, with full image comparison being performed on only a small percentage of the database  
10 considered candidate matches. Due to the nature of ballistic items and the distortions to which they are  
11 subjected, and to variations in illumination resulting from aging, positioning, focus, personnel, and laboratory  
12 differences, visual imaging does not provide sufficient consistency and reproducibility of feature location and  
13 characteristics to facilitate such precise matching.

#### 14 15 **DEFINITIONS**

16 Gun – device with barrel which fires a projectile, including pistols, revolvers, semiautomatics, rifles, and  
17 shotguns.

18 Bore – diameter and inside surface of a gun; it may be smooth or grooved

19 Riflings – spiraled, grooved markings inside a barrel

20 Trigger - mechanism used to fire the gun by releasing the hammer which strikes a firing pin housed  
21 inside the breech block

22 Firing Pin – mechanism driven into the primer area of a cartridge to initiate firing the projectile

23 Primer – firing pin strike can be center fire or rim fire

24 Cartridge - case containing the projectile or bullet; it may be reloaded for repeated use

25 Forensic Item – any item used as a weapon, or item associated with a crime which may display marks  
26 related to the crime, including marks made on a human body

27 Ballistic Item – gun, bullet, shell casing, or other weapon, projectile, or element including the hands  
28 which may cause or receive marks or residue associated with firing a weapon

1 Infrared camera – an imaging device whose detectors are sensitive in a spectral band between 1  
2 and 14 micron; the infrared camera may have an associated spectral filter which blocks or transmits  
3 segments of its band.

4 Active infrared imaging – heating or cooling the subject of the infrared image, including by sunlight,  
5 hot or cold air, immersion in fluids, application of flame or ice, or other means.

6 Image sequence – one or more images of a forensic item in which the camera is focused on  
7 specific features of the item

8 Reduced image sequence – an image sequence formed by selection of images which are of  
9 keenest interest to a ballistics examiner

10 Features – extended marks on a forensic item visible in visual or infrared imagery caused during  
11 the manufacturing process or during use. They include pits, scratches, embossing, gouges, residue, and  
12 machining flaws

13 Extracted feature sequence – a processed image sequence or reduced image sequence in which  
14 only features are shown

15 Image sequence focus montage – Iso referred to as a montage - combined sharp focus portions of  
16 multiple images in a sequence to make one or more composite images

17 Class characteristics – features related to a particular type of weapon or ammunition and include:  
18 calibre of weapon, type of ammunition, type of casing, number of lands and grooves and twist angle.

19 Tool Marks – residual markings left on an item which has been manufactured or worked using a  
20 tool. In the case of a ballistic item, it can be left by the manufacturing process, by incidental use, or by use  
21 as a weapon.

22 Weapon characteristics – features related to a particular weapon and may include firing pin  
23 impression, breech face marks, ejector gouge, extractor mark, striations, land and groove locations

24 Residue – materials deposited on a ballistic item, including blood, oil, gun powder, dirt, grease,  
25 fingerprints, body tissue, and building materials.

26 Manufacturers Mark – embossed or indented markings made during the manufacturing process, on  
27 cartridges this would commonly include type and calibre of ammunition such as “30-30 WIN”

28 Orientation - position of the ballistic item relative to the axes of the camera  
29

Siblings – two bullets, bullet fragments, or shell casings known to have been shot from the same weapon with the same barrel.

## INTRODUCTION TO THE INVENTION

Infrared imaging of guns, fired bullets and spent casings can provide detailed definition of characteristic features free from the shadowing, glint, and focus blur associated with visible light imaging. Although IR imaging is normally associated with measurements of temperature, the imagery from an IR camera results from emissivity and geometry variations in addition to thermal changes. The tool marks which are of forensic interest on bullets and casings are associated with significant emissivity differences. In particular, deep grooves such as firing pin indentations and primer edges create highly detailed observable features in IR imagery even at ambient temperature. Use of IR imaging for ballistics identification is therefore not intended to measure temperature differences, but rather to display and analyze emissivity and geometric differences associated with indentations and embossed features of the ballistic item.

The features seen in the infrared images do not vary in position or extent as a function of illumination as do visible images. Therefore they provide stable references for alignment with other images for comparison purposes. Additional details can be obtained by active IR imaging, in which the temperature of the gun, projectile or casing is varied. This provides a sequence of images in which certain features of interest are particularly apparent at specific temperatures. This process is suggested only when it is necessary to enhance very faint features.

### Summary of Benefits of IR Ballistics Identification

- Increased accuracy, speed, cost effectiveness, and ease of use.
- Provides greater definition of individual characteristics.
- No need for high energy controlled illumination
- In conjunction with visible imaging, can discriminate real features from artifacts in visual images.
- Increased automation reduces personnel requirements and personnel-induced variations..
- Allows examiner to select particular features to be matched, speeding the search and reducing false positives.
- Consistently discriminates between Land and Groove markings
- No shadows or glint created
- No variations induced by different lighting at different facilities

## INFRARED IMAGING IN BALLISTICS IDENTIFICATION

The class characteristics of the ammunition and weapon include: calibre of ammunition, type of weapon, number of land marks, direction of twist of land marks, land mark width, angle of twist of land mark. All of this information can be obtained from infrared images, given that sufficient images at the correct temperature ranges are available.

The individual characteristics of the ammunition and weapon include the particular surface condition and shape of the bore, the particular striations imposed on the bullet, and the particular markings imposed on the casing. These characteristics can also be determined using infrared images. Even when caseless Teflon bullets are used, active infrared imaging may exploit minute markings transferred to the bullet by the barrel and firing charge. A rotating IR probe, similar to endoscopic cameras in medical use, can produce a detailed image of a gun barrel, which can then be matched against casings and bullets which are suspected of having been fired from that gun. In some instances, this may be preferable to making test firings from the weapon; particularly if the weapon is considered unsafe, or if it is necessary to preserve the weapon in its present condition as to residue etc.

The weapon itself should display identifying information such as the manufacturer's name and logo and serial number. If the serial number has been removed, use of infrared imaging can assist in recovering the information, since the emissivity of the area will be affected by attempts to file off or chemically etch off the serial number. By heating and cooling the weapon, a number of corresponding but different images can be obtained and all used to assist the reconstruction effort.

Characteristic weapons-identifying markings to be imaged and compared, include:

- Scratches made on the bullet by the lands and grooves
- Scratches made on the shell casing by the extractor and ejector of semiautomatic weapons
- Indentation on the casing made by firing pin and breech face.
- Indications of refilling and reusing the casing
- Lands and grooves within the gun barrel
- Trace items in residue deposited on the shooter's hand, within the gun, on the victim, on the bullet and casing, and on other targets.

Heat conduction analyses can be performed by heating the ballistic item and imaging it while it cools. Estimates of the depth and volume of indentations, striations, and gouges can be made based on their cooling rates. The material composition of each area of the item must be considered.

## EVALUATION OF BALLISTIC MATCHING SYSTEMS

Current systems, such as DrugFire, compare an unknown ballistic item's image to all corresponding images in a database, producing a correlation value for each. Database images are then re-ordered based upon that correlation value, with the highest correlation ranked first. In controlled testing where the identities of all siblings are known, a measure of the accuracy and efficiency of the matching engine is the position of siblings in the re-ordering. The results shown below in the left column are taken from the DrugFire system manufactured by Mnemonics Systems [nc.. The right column shows the use of a different matching engine [FlashCorrelation® patented by the inventor] with the same visual image database as used by Mnemonics. 1157 shell casings from 229 weapons were used for the tests. The images were all taken with a conventional videomicroscope camera. MIKOS did not have the opportunity to collect its own images of the casings. Therefore, no infrared images were obtained or used for this comparison test. The purpose of this table is merely to show how ballistic matching systems are evaluated. In a smaller test, the use of infrared imagery produced significant additional improvement in position of siblings over the use of visual imagery, with nearly all siblings clustered at the very top of the ranking.

### **BALLISTICS MATCHING ENGINE COMPARISON TEST**

1157 SHELL CASING IMAGES FROM 229 WEAPONS;  
Siblings are casings fired from the same weapon

#### **Percent of Siblings Ranked in the top P%**

| P%  | MNEMONICS | MIKOS    |
|-----|-----------|----------|
| 2   | no report | 45.55 #  |
| 5   | no report | 57.56 #  |
| 10  | 49.40     | 68.03 #  |
| 20  | 63.60     | 79.56 #  |
| 30  | 72.30     | 85.68 #  |
| 40  | 79.30     | 90.76 #  |
| 50  | 84.80     | 94.38 #  |
| 60  | 88.70     | 97.04 #  |
| 70  | 93.20     | 99.38 #  |
| 80  | 96.50     | 100.00 # |
| 90  | 98.90     | 100.00 # |
| 100 | 100.00    | 100.00 # |

"P" is a ranking order from 2% to 100%. Each image in the database is compared against every other, and the database is reordered by the degree of similarity with the target image. Each sibling of the target image (images of other casings fired from the same weapon) is located on the reordered list and included in the corresponding P value. Ideally all siblings would occur at the top of the rankings. The process is

1 performed for each image in the test set database in order to obtain a statistical assessment of overall  
2 system performance.

3 Best indication of the relative performance of two systems would be to compare their results at  $P=2\%$   
4 since as  $P$  gets larger towards 100% any matching technique would produce similar results. In particular, at  
5  $P=100\%$  all matching techniques achieve 100% inclusion. Mnemonics did not report rankings for  $P$  less than  
6 10%. If we extrapolate the Mnemonics results to 2%, the expected value was 25%. Comparing that with  
7 the 46% MIKOS value indicates that the MIKOS matching engine achieved 80% more detections at 2% than  
8 did Mnemonics.

9 The intent of the ballistics matching system is to find the best matches in the database and display them  
10 to a ballistics examiner who makes the final determination as to whether a match exists. The goal is to  
11 minimize the work of the examiner without sacrificing accuracy. The growing size of current databases  
12 requires a higher degree of automation to find links between crimes and suspects before either the statutes  
13 of limitations or the suspects expire..

## 14 15 **SUMMARY OF THE INVENTION**

16 The present invention relates to a method and apparatus for comparing patterns of marks found on  
17 ballistic items (including guns, bullets and shell casings) to determine whether they have common  
18 characteristics which would indicate that the bullet or casing has been fired from a particular weapon. The  
19 invention provides the ability to rapidly match images of an unknown ballistic item with a database of images  
20 of ballistic items including guns or ammunition fired from known weapons or unknown weapons, providing  
21 linkage between weapons or crimes or other events from which the guns, bullets or casings were  
22 recovered.

## 23 24 **IR IMAGING PROVIDES CONSISTENT FEATURE EXTRACTION AND CHARACTERIZATION**

25 Infrared imaging of guns, fired bullets and spent casings can provide consistent and detailed definition  
26 of characteristic features free from the shadowing, glint, and focus blur associated with visible light imaging.  
27 Well-defined infrared imagery from casings and bullets is obtained even with the item at ambient  
28 temperature. The apparent temperature differences seen are due to variations in materials, and emissivity  
29 differences associated with geometry factors, and depth of markings. Therefore, the firing pin indentation,  
30 its surrounding area, the primer area, and the outer ring will all appear to be at different temperatures,

although all are at room ambient. Use of the thermal imaging IR camera is therefore not intended to measure temperature differences, but rather to extract features based upon emissivity and materials differences. The resulting features can be automatically characterized, classified, and then matched against portions of the database having similarly characterized features. Since the features do not vary in position or extent due to imaging conditions, alignment of candidate matches is facilitated by

## **ACTIVE INFRARED IMAGERY ENHANCES THE FEATURES BUT IS OPTIONAL**

Active IR imaging, in which the temperature of the gun, projectile or casing is varied, provides a collection of images at the various temperatures. Certain features of interest are particularly apparent at specific temperatures. Features associated with different materials such as the primer, or with emissivity differences such as caused by abrasion, are more well defined when viewed with an IR camera. For a given type of gun or ammunition a set of temperatures can be determined such that the sequence of images resulting from heating or cooling the gun, projectile or casing to those temperatures provides an optimized data set for matching against a database. Matching can be done using standard image processing techniques such as optical or digital correlation, or using proprietary techniques such as Flash Correlation (US 5,583,950 Method and Apparatus for N-dimensional Image Identification and Analysis).

If the ballistic item is heated and then imaged as it cools, the technique provides a sequence of images at various temperatures for each item. At certain temperatures, depending upon the composition material of the item, specific markings are enhanced. For example: serial numbers on a gun, manufacturers markings on a shell casing, striations on a bullet caused by the gun barrel, fingerprints, firing pin indentation and breech face marks on a shell casing can be characterized by size, shape, and relative location in a sequence of infrared images, as a function of imposed temperature. A feature template can be produced for each image in each sequence, by thresholding hot and cold values or other standard feature extraction techniques commonly used in image processing.

## **FEATURE EXTRACTION AND CHARACTERIZATION PROVIDES DATABASE PARTITIONING**

Any extended area of the infrared image with apparent temperature differences from the surrounding area may be considered a feature. Using the sequence of images or extracted feature templates, significant features can be extracted and characterized prior to use of the matching engine. Characteristics of the infrared features such as area, dimensions, depth, focus setting, variation in depth and apparent

temperature, shape, inclusion of subfeatures, apparent temperature, location relative to center and edges of the ballistic item, ratio of perimeter to area, distance and vector to other features, persistence or exclusion over a range of imposed temperatures, persistence or exclusion under specific spectral filters may be computed and used to characterize the set of features seen in an image sequence or montage. If visual images are also being processed, then the visual characteristics of features seen in the infrared may also be used to characterize the features for a particular ballistic item.

By storing feature characteristics in a relational database, possible matches can be more quickly located. In general it is not necessary to find all matching ballistic items, such as all sibling casings. A single positive match provides links to others already in the database. As an example, for an unknown casing, determine the characteristics of: (1) distance from firing pin indentation to the center of the casing, (2) depth of indent, (3) angle of breech face marks relative to the line from firing pin indent to center, and (4) existence of ejector gouge. Then locate other items in the database which have some or all of the same characteristics. This is referred to as partitioning the database into candidate matches and other items. Candidate matches are then subjected to further processing. The corresponding image sequences or montages can be compared and those not sufficiently similar excluded from the candidates list. Remaining candidates are then presented for review by a ballistics examiner.

Selection of features to be characterized, and the characterization process, can be fully automated or manually assisted. Partitioning significantly reduces the search time required to look for matches, but requires knowledge about the variations which may occur in firings of a particular weapon. For example, changing the ammunition size or type used will change the markings imposed by the weapon. Therefore, in conducting a search against a database, to reduce the occurrence of false negative results, the criteria for including a database item as a candidate matching item must be considered relative to possible variations such as: whether the weapon has interchangeable barrels, whether it might be used with different sized ammunition, whether it might have been cleaned, whether it might have had heavy use between the database entry and the current characterization.

The precise extraction and matching of feature characteristics which is the method of this patent cannot be effectively performed on visual images due to the nature of the ballistic items, which produce illumination artifacts such as shadows and glint, and cause confusion of lands and grooves, and obliteration of fine details in deep markings such as firing pin indentations.

Class characteristics of ammunition and weapons include: calibre of ammunition, type of weapon, number of lands, direction of twist of land marks, land mark width, angle of twist of land mark. All of this information can be obtained from infrared images.

Individual characteristics of the ammunition and weapon include: the particular surface condition and shape of the bore, the particular striations imposed on the bullet, and the particular markings imposed on the casing. These characteristics can also be determined using infrared images. Even when caseless Teflon bullets are used, active infrared imaging may exploit minute markings transferred to the bullet by the barrel and firing charge. A rotating IR probe, similar to endoscopic cameras in medical use, can produce a detailed image of a gun barrel, which can then be matched against casings and bullets which are suspected of having been fired from that gun. In some instances, this may be preferable to making test firings from the weapon; particularly if the weapon is considered unsafe, or if it is necessary to preserve the weapon in its present condition as to residue etc.

The weapon itself should display identifying information such as the manufacturer's name and logo and serial number. If the serial number has been removed, use of infrared imaging can assist in recovering the information, since the emissivity of the area will be affected by attempts to file off or chemically etch off the serial number. By heating and cooling the weapon, a number of corresponding but different images can be obtained and all used to assist the reconstruction effort.

#### **EXAMPLES OF CHARACTERIZATION OF FEATURES:**

In matching casing faces, the database can be characterized according to:

- Distance off center of firing pin indent.
- Depth of firing pin indent.
- Percent of face area having breech marks.
- Depth of breech marks.
- Angle between breech marks and firing pin vector, which connects the deepest indentation point with the closest spot on the casing edge.
- Position of ejector marks relative to firing pin and breech face marks.

Images in the database can be oriented such that the flare-out of the primer is pointing to 3:00 (three o'clock) if it is not symmetrical; if it is symmetrical, then the firing pin indentation vector is set to be

1 pointing to 3:00 if it is off-center; if it is also centered, then the breech marks are set parallel to the horizontal  
2 (3:00 – 9:00).

3 For bullets, the database can be characterized according to:

- 4 • Calibre of bullet
- 5 • Material
- 6 • Length
- 7 • Number of twists
- 8 • Length of striations of maximum depth
- 9 • Number of striations vs. Length
- 10 • Relative positions of end points of striations.

11 For casing sides the database can be characterized according to:

- 12 • Calibre of bullet
- 13 • Material
- 14 • Presence of ejector mark.
- 15 • Presence of extractor mark.
- 16 • Number of striations vs. Length

Images in the casing sides and bullet databases should be formed as composites of the multiple frames taken as the bullet or casing is rotated. The composite images can be oriented so as to align striations with the horizontal plane of the image. Due to spiraling of the lands and grooves, image segments must be composed to create an image of the resulting striation pattern from the various segments imaged.

21 For images derived from thermal probes of gun barrels, the database can be characterized  
22 according to:

- 23 • Calibre weapon
- 24 • Twisted bore or not.
- 25 • Number of lands and grooves
- 26 • Angle of twist.
- 27 • Relative positions of start and stop points of lands and grooves.

28           The resulting strip image should be formed into a 2-dimensional image as if the gun barrel were  
29   sliced open and laid flat, and should be oriented such that the lands and grooves are horizontal in the  
30   image.

## 1 DETECTION OF ILLUMINATION-INDUCED ARTIFACTS IN VISUAL IMAGES

2 Since existing databases of ballistic images are all taken in the visible spectrum, utilizing those  
 3 databases requires that new images also be taken in the visible domain. Due to the superior advantages of  
 4 infrared imaging, it is anticipated that at some time in the future IR ballistic imaging will become standard.  
 5 Meanwhile, IR images can begin to be collected for current and future use, and also to aid in exploitation of  
 6 the existing databases.

7 By imaging in both IR and visible bands, extracting and characterizing features in each band, and  
 8 comparing the results, apparent visible features which are in fact illumination-induced artifacts can be  
 9 eliminated from the characterization of a ballistic item prior to matching against the database. Any true  
 10 visual feature will also appear in the IR image. Eliminating artifacts will reduce the false positive error rate in  
 11 visual matching.

12 True visible features such as striations may suffer from apparent reversal of deep and tall (e.g. land and  
 13 groove) markings due to the angle of illumination. The comparable IR feature can be used as a reference  
 14 to locally vary the gray-scale allocation (look-up table or LUT) in the visible image to best match that of the  
 15 IR image. The result will standardize the appearance of the striations in the visible image, and improve the  
 16 accuracy of the matching system.

## 18 SEPARATION OF MANUFACTURERS MARKS FROM WEAPONS MARKS

19 Certain markings imposed by a manufacturer, such as the calibre and manufacturer's identity on  
 20 shell casings, have a characteristic depth or height which facilitates separation of those markings based  
 21 upon their apparent temperature difference in infrared images. The distinction between those features and  
 22 others may be further enhanced by heating or cooling the ballistic item. A template may be made from the  
 23 infrared sequence which can be used to separate the manufacturers and weapons marks in the  
 24 corresponding visible images. This processing step allows for separate consideration of the two sources of  
 25 marks, with the realization that the two types of marks may overlap and so subtracting one type may create  
 26 changes in the feature characteristics of the other which must be accommodated in the matching engine.

## 28 INFRARED IMAGES TO IDENTIFY RESIDUE IN VISUAL OR INFRARED IMAGE MATCHING

29 Infrared imaging can employ optical filters to assist in determining the presence and composition of  
 30 gunshot residue, as well as blood, body tissue, building materials and other matter deposited on bullets

1 during their trajectory. Nitrocellulose forms carbon and the oxides of nitrate and nitrite. Other components  
2 may contain barium, antimony, cooper, and lead oxides or salts. Center core primers, found in most  
3 ammunition, traditionally have contained all four chemicals, but lead is now less prevalent, and rim fire  
4 primers, used almost exclusively for .22 calibre, often have no barium or antimony.

5 By the use of filters, the presence of residue on the ballistic item can be determined and classified.  
6 Apparent features of the ballistic item which are actually residue can be ignored for purposes of automatic  
7 matching against a database. This is particularly useful in the case where residue produces an apparent  
8 feature or obliterates existing features. If residue is detected, the system can provide instructions to the  
9 system user that the particular ballistic item needs to be cleaned prior to further imaging.

10 Infrared imaging of the hands of suspects can also utilize spectral filters to search for gunshot  
11 residue. This provides a possible immediate testing capability when a firearms investigator is not available,  
12 or the scene is too contaminated to facilitate clean lifting of debris from the suspect for later analysis. By  
13 combining infrared imaging of the hands and face of the suspect, the issue of chain of custody of the hands  
14 samples is eliminated, since infrared images of each person's face is unique. If the infrared camera  
15 annotates date and time, it minimizes the level of training and time required at the crime scene. Lift  
16 samples can be taken and studied via chemical analysis using a scanning electron microscope, as is  
17 traditionally done, in addition to the infrared analysis. For this application, an IR camera with automatic  
18 sequencing of optical filters and video or digital output recording provides the best setup for archival  
19 purposes and to support future analysis.

## 21 **APPLICATION OF INFRARED IMAGING TO ADVANCED WEAPONRY**

22 For the future, increasingly sensitive imaging and matching techniques are required: Teflon-coated  
23 bullets do not pick up land and groove impressions well. Caseless bullets have been developed which  
24 leave no shell casings after firing. The weapon used is an electronic .223 calibre rifle, called Lightning  
25 Fire, made by Jaguar Sport. The shell exists but is constructed of propellant only. When the trigger is  
26 pulled, an electric charge, not a firing pin, detonates the propellant, burning the entire casing. The  
27 combination of the self-destroying shell case and Teflon bullet will provide very little evidence for evaluation.  
28 Active infrared imaging of such bullets may provide sufficient information for identification and matching.

## 1 IMAGE MONTAGE CREATION

2 A composite image or images can be created by combining the best focused local image of each true  
3 feature of a ballistic item to create an image of the entire item in which each feature is in its relative position  
4 and in focus. The montaged images can be displayed to the ballistics examiner and/or first used in  
5 automated correlation processing to determine candidate matching items. This step can be performed for  
6 either visible or infrared image sequences and matching procedures.

## 8 DESCRIPTION OF THE APPARATUS

9 The apparatus consists of the following components:

- 10 1. Infrared imaging microscope having radiometric calibration for each image frame output, such that  
11 a given gray level corresponds to a particular apparent temperature. Variable focus optics allow for detailed  
12 in-focus imaging over the full range of depth and height of the ballistic item features.
- 13 2. Shroud to avoid ambient light striking the ballistic item to cause reflections or heating.
- 14 3. Holders for shell casings such that the back end is viewed normal to the camera axis.
- 15 4. Holders for shell casings such that the side is normal to the camera axis and the casing can be  
16 rotated for a full 360° image.
- 17 5. Holder for essentially undeformed bullets such that the bullet can be rotated and all of the surface  
18 can be imaged normal to the camera axis.
- 19 6. Holders for deformed bullets such that multiple images can be taken which will encompass the  
20 entire surface area. Assume the bullet may have no obvious axis or center; the need is to completely image  
21 the surface. Multiple positionings may be needed.
- 22 7. Holder for gun which facilitates operation of an infrared probe which has a helical scanning rotating  
23 head and forms an infrared image of the inside of the barrel of a gun as it cools.
- 24 8. (Optional) Heater subsystem which can be on-line: radiant heat lamps, hot air, direct contact  
25 electric heat; or off-line: boiling in water or other liquid, heating in a controlled oven.
- 26 9. (Optional) Spectral filters, which can be used to obtain additional image information such as the  
27 composition of the ballistic item, including material of the casing, material of the bullet, type of primer.  
28 Alternately, the system user can determine these characteristics.
- 29 10. Feature Extraction Engine, which can be image processing software, firmware or hardware to  
30 locate local areas of interest in the image.

11. Feature Characterizing Engine, which can be image processing software, firmware, or hardware to perform measurements of the features and associate those measurements with the image in a database.
12. Focus position indicator, which annotates each image in a sequence with the focus position at which it was imaged.
13. Image montage generator, which determines the best-focused image of each feature, and generates a composite image or images in which all features are present and each is in focus.
14. Matching engine which correlates a mounted image of an unknown ballistic item against images in a database and rank orders or thresholds the results to produce a list of candidate matching items.
15. Examiner workstation which interacts with the ballistics examiner and displays the candidate matching item images, feature maps, correlation values, and characteristics of the ballistic items and their comparisons. The workstation allows him to input queries and receive responses in display or hard copy format. It generates, maintains, and accesses databases of ballistic item images and features and information annotated by the user. It also includes a highlighter function which allows examiner to designate features of interest in an unknown ballistic item, for matching against a database. The highlighter can utilize a light pen, touch screen display, graphics tablet, or other interactive device.
16. For Visible image matching, the apparatus also includes a video microscope with matching lenses to the IR microscope, and a database of visible images.
17. Image processor subsystem acquires images from the cameras including either direct digital output or digitized analog output of the infrared and visible cameras. It standardizes image orientation including rotation, translation, and alignment based upon features in the image.

## BRIEF DESCRIPTION OF THE DRAWINGS

Many details and advantages of the present invention will be apparent to those skilled in the art when this document is read in conjunction with the attached drawings where matching reference numbers are applied to matching items and where:

Figures 1a, 1b, and 1c are visible images of the primer areas of sibling casings. The image illustrate the effects of illumination variations and artifacts. In particular, the firing pin indentations in the centers lack any details, and each shows glint from the illumination. Each image is oriented based upon the breech face marks and the position of the firing pin indentation. 1a has the best detailed primer area. The illumination of 1b causes much of the breech face markings to be lost., and reverses the appearance of the feature at

1 10:00 from a white to a dark line inside a grey area. The firing pin indent also appears smaller than in a. In  
 2 c, a slight variation in the illumination angle make the firing pin indentation appear to be raised up instead.  
 3 Turning the image upsidedown makes it appear to be an indentation; however then the position of the  
 4 indentation is incorrect. Depending on the match engine, these siblings may not be detected as matches  
 5 based upon these visible images due to the illumination-induced variations.

6 Figure 2 shows the apparatus for a dual band IR/visible imaging and matching ballistic identification  
 7 system. The split screen shows two IR images being compared. A four-way split screen can display the  
 8 corresponding visible images also at the same time.

9 Figure 3 is an infrared image of a shell casing end clearly showing the manufacturers marks and  
 10 weapons-related marks. This item was heated to 105°F.

11 Figure 4 is an infrared image of a shell casing end at ambient temperature, with focus set to best  
 12 detail the firing pin indentation.

13 Figure 5 is an infrared image of the edge of a shell casing at ambient temperature, with focus set  
 14 for an ejector mark.

15 Figure 6 is an infrared image of a shell casing at ambient temperature, with focus set for a  
 16 distinctive tool mark.

17 Figure 7 is an infrared image of a shell casing at ambient temperature, with focus set for a  
 18 distinctive tool mark in the primer area.

19 Figure 8 is a magnified infrared image of the firing pin indentation in a shell casing at room  
 20 temperature.

21 Figure 9a and 9b are magnified infrared images of firing pin indentations of siblings.

22 Figure 10a, b, c, and d show the resulting infrared images of shell casings at differing temperatures.  
 23 Certain features are more apparent at different temperatures.

24 Figure 11 illustrates the removal of the manufacturers markings from the casing image prior to  
 25 matching.

26 Figure 12 illustrates minutiae obtained from Figure 11. In this example, minutiae were defined as  
 27 pixels whose nearest neighbors had grey values differing by more than 8 gray levels. Matching can be  
 28 performed based upon the minutiae, analogous to matching of fingerprint minutiae.

29 Figure 13 presents a block diagram of the apparatus configured with the following subsystems:

Figure 12 illustrates minutiae obtained from Figure 11. In this example, minutiae were defined as pixels whose nearest neighbors had grey values differing by more than 8 gray levels. Matching can be performed based upon the minutiae, analogous to matching of fingerprint minutiae.

Figure 13 presents a block diagram of the apparatus configured with the following subsystems:

(1) image capture and display, including the ballistic examiner's display, feature highlighter, and interactive devices.

(2) feature extraction and characterization.

(3) database matching and updating.

Figure 14 presents a hypothetical graph of the apparent size of a feature as a function of gray scale values (or temperatures) included in the feature, using different spectral bands. Such graphs can be used to automatically determine the material of the item including principal and trace components, the type of weapon, and the manufacturer.

#### **DETAILED DESCRIPTION OF THE FIRST EMBODIMENT –**

##### **USING INFRARED IMAGES TO REFINE VISIBLE IMAGE DETAILS FOR BALLISTICS IDENTIFICATION IMAGE AND INFORMATION CAPTURE**

A ballistic item 10 is placed in a holder 12 and surrounded by a shroud 14 covering it and an infrared camera 16 such that external lighting and heating sources are blocked. The camera focus mechanism 18 is varied over a range such that all details of the infrared image of the ballistic item are clearly captured in a sequence of infrared images 20.

Optionally, one or more spectral filters 30 can be installed and additional sequences of infrared images obtained. Optionally, a heater 32 can be used to raise the temperature of the ballistic item and additional sequences of infrared images obtained for the item at the elevated temperature and as it cools.

A controlled light source 110 is then turned on to illuminate the ballistic item and a video camera 116 is used to produce a sequence of visible images 120 by varying the focus mechanism 18.

Each image is annotated with date and time, workstation #, item temperature, focus setting, and item reference number. The focus and image capture processes can be automated such that a succession of minute variations in focus is performed and an image taken at each step, or the focus and image capture can be manually controlled using an examiner's workstation consisting of a display screen 22 and input controls 24 including any combination of keyboard, mouse, voice, or similar device. The workstation also

Text information is entered which identifies the ballistics item and related information such as case #, weapon type, ammunition type, location where found, etc. That information can be read from an evidence tag using a bar code reader 28 or input through the controls of the examiners workstation such as by keyboard. The text information can be displayed on the screen 22 along with the corresponding annotated image.

Both text information and image sequences are stored in an infrared image sequence database 26 and a visible image sequence database 126.

## **FEATURE EXTRACTION AND CHARACTERIZATION**

The sequences of visible images are processed to extract and characterize apparent features at 142 using any of various standard automated image processing techniques or by manual highlighting by the examiner. Characterization a minimum includes the relative positions of features, their shape, their area and perimeter length, and variation in gray scale distribution within the feature. Similar processing is performed at 42 on the infrared sequences using the same or similar processing.

For each visible feature, one image is selected from the sequence in which that feature is in sharp focus. The feature area of that image is extracted and used to create a montaged visible image 138 in which each feature is shown and each is in sharp focus. The same is done for the infrared sequence to create a montaged infrared image 38. Each montaged image is associated with the characterizations of the associated features at 42 and 142.

## **IMAGE COMPARISON AND CORRECTIONS TO VISIBLE IMAGES**

The characteristics of the montaged visible image 138 and montaged infrared image 38 are compared at 136. Any feature of the visible montaged image 138 which does not have a corresponding infrared montaged feature in image 38 is removed from image 138. Correspondence requires at a minimum overlapping locations and similar shapes. Those removed visible features are considered to be illumination-induced artifacts. Any visible feature which has a corresponding infrared feature, but which differs in gray scale distribution from the IR feature is subjected to variation in its gray scale allocation or LUT 134 to find the best correlation with the corresponding infrared feature. Those visible features are considered to have illumination-induced gray scale reversals. Any infrared feature which does not have a corresponding visible feature is considered to represent a possible true feature hidden in the visible image

1 due to shadow. At the option of the examiner, such features can be (1) copied from the infrared montaged  
2 image to the visible montaged image, (2) annotated such as in color on the visible montaged image, (3)  
3 tested by the use of spectral filters and/or heating to determine if it results from residue, in which case the  
4 item should be cleaned and re-imaged.

5 The resulting montaged infrared and visible images, along with their characteristics and textual  
6 information are entered into a database of infrared characterizations 50 and enhanced visible  
7 characterizations 150 of unknown ballistic items. The enhanced visible characterization can then be used  
8 with current ballistic identification methods and apparatus, producing more accurate results due to the  
9 elimination of illumination-induced artifacts, and the detection of hidden features due to shadow.

## 11 DETAILED DESCRIPTION OF THE SECOND EMBODIMENT –

### 12 BALLISTICS IDENTIFICATION THROUGH MATCHING INFRARED CHARACTERISTICS

13 When infrared imaging alone is used for ballistics identification, without use of corresponding visible  
14 images, then components 100, 118, 120, 126, 138, 142, 134, 150 and references to visible images,  
15 sequences, features, and montages can be eliminated from the apparatus description.

### 17 IMAGE AND INFORMATION CAPTURE

18 A ballistic item 10 is placed in a holder 12 and surrounded by a shroud 14 covering it and an  
19 infrared camera 16 such that external lighting and heating sources are blocked. The camera focus  
20 mechanism 18 is varied over a range such that all details of the infrared image of the ballistic item are  
21 clearly captured in a sequence of infrared images 20.

22 Optionally, one or more spectral filters 30 can be installed and additional sequences of infrared  
23 images obtained. Optionally, a heater 32 can be used to raise the temperature of the ballistic item and  
24 additional sequences of infrared images obtained for the item at the elevated temperature and as it cools.

25 Each image is annotated with date and time, workstation #, item temperature, focus setting, and  
26 item reference number. The focus and image capture processes can be automated such that a succession  
27 of minute variations in focus is performed and an image taken at each step, or the focus and image capture  
28 can be manually controlled using an examiners workstation consisting of a display screen 22 and input  
29 controls 24 including any combination of keyboard, mouse, voice, or similar device. The workstation also  
30 contains highlighting device 90 for manually specifying areas of images or textual information of particular

interest to the examiner. The highlighter can be any combination of touch screen, lightpen, graphics tablet, or similar device. The display 22 has the ability to mosaic several images on a single screen.

Text information is entered which identifies the ballistics item and related information such as case #, weapon type, ammunition type, location where found, etc. That information can be read from an evidence tag using a bar code reader 28 or input through the controls of the examiners workstation such as by keyboard. The text information can be displayed on the screen 22 along with the corresponding annotated image.

Both text information and image sequences are stored in an image sequence database 26.

## FEATURE EXTRACTION AND CHARACTERIZATION

The sequences of infrared images are processed to extract and characterize apparent features at 42 using any of various standard automated image processing techniques or by manual highlighting by the examiner. Characterization at a minimum includes the relative positions of features, their shape, their area and perimeter length, and variation in gray scale distribution within the feature

For each apparent infrared feature, one image is selected from the sequence in which that feature is in sharp focus. The feature area of that image is extracted and used to create a montaged infrared image 38 in which each feature is shown and each is in sharp focus. If there is the chance that debris may remain on the ballistic item, then apparent features may in fact be debris. This event can be tested for by comparing corresponding focus images using different spectral filters 30. Apparent features which persist through a range of filters are considered actual features. Each montaged image is then associated with the characterizations of the associated features at 42.

## IDENTIFICATION USING MATCHING

When the unknown ballistic item characterized in 50 has been identified or linked with other known items, by a ballistics examiner or an automated system, its file is move to relational database 60 which then includes (1) textual information related to the case, its disposition, location of the item, names and dates, weapon information and links to other forensic and law enforcement databases; (2) images which may include the montaged feature images alone or also the image sequences, and may also include highlights created by a ballistics examiner and corresponding notes, which should be displayed in color for emphasis;

and (3) feature characteristics including a summary of the number and types of features seen, and details on each feature including type, shape, size, location, and variation in gray scale and edge effects.

Database 60 will contain characterization of known or linked ballistic items. When an unknown item 10 is presented for identification, it is processed as detailed above to produce its characterization at 50. The resulting characteristics are used to select initial candidates from the database 60 based upon text, image, and feature characteristics which are relatively immune to error or variation. For example, the calibre of ammunition. In matching shell casings, if the unknown firing pin indentation is centered, only database entries with centered firing pins are considered as potential candidates. The presence or breech face markings, ejector or extractor marks may also be considered relatively immune to error or variation.

The initial candidate matches are then further processed using the text matching engine 70 which might provide for example the date of manufacture of the weapon, meaning that all ballistic items collected prior to that date need not be considered as matches. Other information is compared and scored as to similarity, such as information about the type of crime associated with the ballistics item, the locale where the item was collected, the presence of other similar items at the same collection, etc. The similarity score will generally not exclude candidates from further consideration, but may influence their rank ordering in presentation to a ballistics examiner for consideration below.

Remaining candidate matches are then further processed using the feature matching engine 72 which first compares summary characteristics such as the number and type of features, and then compares the details of each feature of the unknown and candidate items. Various metrics or scoring techniques can be defined to calculate a goodness of match based upon the feature characteristics. Fingerprint matching and face matching technique are especially suitable, with Prokoski et. al U.S. Patent 5/63094, as an example. Candidates which do not correlate sufficiently with the unknown item are not longer considered.

Remaining candidate matches are then further processed by correlating the montaged images using an image processing technique such as Prokoski U.S. Patent 5583950 to produce an image correlation value. Other image processing comparison techniques may be used.

The remaining candidates are then rank ordered based upon their text similarity score, their feature characteristics goodness of match, and their image correlation value. Various algorithms for performing the rank ordering can be used. An effective one is to assign a rank ordering based on each of the three measures, and then perform a composite rank ordering based upon the ordinal sum of the component rank orderings.

1 For various reasons it may be desirable to use only one or two of the three comparison techniques.  
2 The top placing candidates are presented to the ballistics examiner for review on the display 22.  
3 Using interactive controls 24 he can manipulate the imagery to perform further visual matching of  
4 simultaneously displayed unknown and candidate text, feature characteristics, and imagery. His decision  
5 78 for each candidate is either that it is a match or is not a match for the unknown item, and the information  
6 in database 50 is transferred to database 60. When he determines that a match has occurred, then he  
7 indicates through the control mechanism 24 that the previously unknown item is now linked to a particular  
8 candidate 80, If he exhausts the top placing candidates, he then indicates that the unknown item has no  
9 match 82 in the existing database as of the current date.  
10

2025 RELEASE UNDER E.O. 14176

1 I CLAIM:

2

3 1. Method for characterizing a ballistic item including the steps:

4 a. Produce a sequence of digitized infrared images of the item at different focus points such that  
5 the deepest to the highest features are each in sharp focus in at least one image,

6 b. tag each image with the ID of the item,

7 c. tag each image with specifics of the imaging set-up including the focus position, and size of  
8 digitized image array

9 d. store the tagged image sequence in a database

10

11 2. Method of claim 1 with the additional step:

12 e. produce a photomontage from the tagged image sequence in which each section of the montage  
13 image is the corresponding section of the image from the tagged sequence in which that section is in  
14 sharpest focus

15

16 3. Method of claim 1 or 2 with the additional step:

17 f. replace each tagged image in the sequence with a tagged extracted feature image containing  
18 only features at least a specified size extracted from the tagged image

19

20 4. Method of claims 1, 2, or 3 with the additional steps:

21 g. add to each tag weapon-specific ancillary information including calibre, type of ammunition,  
22 direction of twist, number of lands, serial number

23 h. add to each tag incident-specific information including type of crime committed, location where  
24 item was found, associated names, method of crime

25

26 5. Method for identification of a ballistic item including the steps:

27 a. characterize the unknown ballistic item by producing a tagged image sequence

28 b. compare the image sequence with those contained in a database

29 c. determine those sequences in which one or more images are similar to the unknown tagged  
30 image sequence

1 d. display the similar pairs of images to a ballistics examiner who reviews the display and rules that  
2 the unknown ballistic item is a match to an item in the database if the similar pair(s) of images are  
3 sufficiently alike.

4  
5 6. Method of Claim 5. In which step f is performed automatically by further image processing

6  
7 7. Method of Claims 5 or 6 including also the step:

8 e. compare the weapon-specific and incident-specific tagging information of the similar image pairs

9 a. Display the similarities and dissimilarities in the tagging information along with the images for

10 further consideration by a ballistics examiner who reviews the display and rules that the

11 unknown ballistic item is a match to an item in the database if the tagging information as well as

12 the similar pair(s) of images are sufficiently alike.

13  
14 8. Method of Claim 7 in which step i. is performed automatically by further image processing.

15  
16 9. Method for identification of a ballistic item including the steps:

17 a. characterize the unknown ballistic item by producing a tagged extracted feature sequence

18 b. compare the extracted feature sequence with those contained in a database

19 c. determine those sequences in which one or more extracted features are similar to the unknown

20 extracted feature sequence

21 d. display the similar pairs of extracted features to a ballistics examiner who reviews the display

22 and rules that the unknown ballistic item is a match to an item in the database if the similar pair(s) of

23 extracted features are sufficiently alike.

24  
25 10. Method of Claim 9. In which step d is performed automatically by further image processing

26  
27 11. Method of Claims 9 or 10 including also the steps:

28 e. compare the weapon-specific and incident-specific tagging information of the similar extracted

29 feature pairs

1 f. Display the similarities and dissimilarities in the tagging information along with the extracted  
2 features for further consideration by a ballistics examiner who reviews the display and rules that the  
3 unknown ballistic item is a match to an item in the database if the tagging information as well as the similar  
4 pair(s) of extracted features are sufficiently alike.

5  
6 12. Method of Claim 11 in which step f. Is performed automatically by further image processing.

7  
8 13. Method of Claim 1 including also the steps:

9 e. heating or cooling the ballistic item to vary its temperature

10 f. producing an image sequence in which both focus and temperature are varied

11 g. tagging each image with the corresponding temperature.

12  
13 14. Method to identify illumination-induced artifacts in visible light photography of ballistic items including  
14 the steps:

15 a. Produce visible and IR image sequences of the same ballistic item

16 b. extract features from each image in each sequence

17 c. tag as a candidate illumination-induced artifact each feature in a visible image which does not  
18 have a corresponding IR feature

19 d. tag dark visible artifacts as possible shadows and light artifacts as possible glint

20  
21 15. Method of claim 14 in which spectral filters are used to tag certain artifacts as possible debris including  
22 oil, gunpowder, fingerprints.

23  
24 16. Method for distinguishing lands and grooves in visible light photography of ballistic items including the  
25 steps:

26 a. produce visible and IR image sequence of the same ballistic item

27 b. extract features from each image in each sequence

28 c. readjust the look-up table of gray scale allocation for the visible image such that the resulting  
29 image most closely matches that of the IR image

d. Display the resulting visible image which will have more consistent appearance of lands vs. grooves.

17. Method to differentiate manufacturing marks and weapons-related tool marks on shell casings including the steps:

- a. adjust the focus on the IR camera such that the manufacturing marks are in focus
- b. adjust the temperature of the ballistic item such that the manufacturing marks are most distinct from the surrounding area
- b. threshold the resulting image to create a template of the manufacturing marks to be used for matching or for eliminating the marks from that image prior to further matching

18. Method to detect residue on a ballistic item, including the steps:

- a. apply a sequence of spectral filters to the IR camera
- b. for each filter, vary the focus to produce an image sequence
- c. extract features from each image in the sequence
- d. compare the feature sets in images which have the same focus setting but different spectral filters
- e. display those features which are filter-sensitive as possible residue
- f. Annotate features with likely type of residue based upon the filter sensitivity.

19. Apparatus for characterizing a ballistic item including:

- a. IR camera with lenses and focus control
- b. Mechanism for varying the focus control to produce a sequence of images
- c. Image digitizer and storage
- c. Mechanism for tagging images with ancillary information
- d. Feature extractor
- e. Processor for characterizing the features
- f. Processor for creating a montage
- g. Display
- h. Mechanism for positioning the item within the camera field of view

1 20. The apparatus of claim 19 including also the elements:

- 2 i. device for heating the ballistic item
- 3 j. device for measuring the temperature of the ballistic device
- 4 k. device for applying optical filters before the camera lens
- 5 l. mechanism for tagging the resulting images with temperature and filter data

7 21. Apparatus for identifying a ballistic item including the elements of 20 plus:

- 8 m. Database of characterized ballistic items
- 9 n. Database matching engine
- 10 o. Output or display mechanism

12 22. Method for identifying a ballistic item including the steps

- 13 a. for each montaged image in the unknown item database and the known item database produce
- 14 a relative location map as follows:
- 15 b. compute the centroid location for each feature, including all striations, gouges, breech face
- 16 marks, and firing pin indents, where each striation is considered a separate feature.
- 17 c. Compute the distances between each pair of centroids
- 18 d. Tag the distances with the type of feature represented at each end
- 19 e. Match the list of tagged distances with corresponding lists for the known item database.

21 23. Method for separating manufacturers marks from weapons marks in ballistic images, including the  
22 steps:

- 23 a. heating the ballistic item to temperature which enhances the manufacturers marks
- 24 b. producing an infrared image of the ballistic item
- 25 c. producing a template of the areas containing the enhanced manufacturers marks
- 26 d. extracting the template areas to form an image containing the manufacturers marks
- 27 e. the remaining image containng no manufacturers marks but containing weapons marks which did
- 28 not overlay manufacturers marks.

- 1 24. Method for estimating the volume of grooves, indentations and striations in ballistic items including the  
2 steps:
- 3 a. heat the ballistic item to an elevated temperature
  - 4 b. measure the mean temperature of the item using the radiometric infrared camera
  - 5 c. capture a sequence of images as the item cools
  - 6 d. capture for each image the mean temperature using the radiometric camera
  - 7 e. estimate the volume of each depressed feature by determining its heat loss rate relative to the  
8 mean temperature of the item, considering also the materials composition of the item.

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## ABSTRACT

Systematic use of infrared image analysis in conjunction with currently used visible image analysis techniques provides significant improvements in automated analysis of tool marks. In particular, the method and apparatus of this patent identify illumination-induced artifacts such as glint and shadow, detect features such as additional striations hidden by shadows, and correct for apparent reversal of lands and grooves due to the angle of illumination used to obtain the visible images. By using the infrared images to detect and eliminate artifacts and make local corrections to features in the visible images, the resulting matching of visible tool mark images against a database of similar images produces more accurate matching with a greater number of located matches. Since current databases of tool marks, including ballistic signatures, contain visible images only, the use of infrared analysis may be initially limited to pre-processing new images compared with and added to the databases.

As infrared camera prices are reduced, it is predicted that the IR analysis methods of this patent will become the standard matching technique, due to their significant advantages. Infrared analysis of tool marks provides classification, alignment, characterization, comparison, matching and identification of such marks with better specificity and repeatability than analysis in the visible spectrum. In the case of ballistics item matching, the proposed method and apparatus can automatically extract and characterize the marks associated with a particular manufacturing process or caused by a particular weapon including: striations, firing pin indentation, breech, extractor and ejector marks, resulting in more accurate automated matching against databases of bullets, casings, and weapons.

The method can be enhanced by active infrared imaging which includes heating or cooling the item under examination to enhance markings which have different depths of surface features or which are caused by differing emissivities due to surface abrasion or due to differing materials. The method can also be enhanced by imaging using a range of spectral filters. This provides compositional analysis of the material of the ballistic item and the nature of any identified debris on the item.

1 REFERENCES

- 2
- 3 Provisional Patent Application, Method and Apparatus for alignment, comparison, and identification of
- 4 characteristic tool marks, including ballistic signatures, Application 60/087,512 F. J.
- 5 Prokoski, date 10 June 1998
- 6
- 7 National Institute of Justice symposium, Orlando Florida, January 1999, Office of Law Enforcement
- 8 Technology Commercialization, handout and demonstration. Handout titled:
- 9 IRID- Ballistics; Infrared Identification of Shell Casings and Bullets.
- 10
- 11 Tsuneo Uchiyama, National Research Institute of Police Science, Tokyo, Japan, " A Criterion for Land
- 12 Mark Identification", AFTE Journal Vol 20, Number 3, July 1988, pp 236-246
- 13
- 14 Tsuneo Uchiyama, National Research Institute of Police Science, Tokyo, Japan, " A Criterion for Land
- 15 Mark Identification Using Rare Marks", AFTE Journal Vol 20, Number 3, July 1988, pp 260-264.
- 16
- 17 Tsuneo Uchiyama, National Research Institute of Police Science, Tokyo, Japan, " Automatic Comparison
- 18 Model of Land Marks", AFTE Journal Vol 20, Number 3, July 1988, pp 250-259.
- 19
- 20 Baldur et al., US Patent 5,390,108, Feb 14 1995, Computer Automated Bullet Analysis Apparatus.
- 21
- 22
- 23

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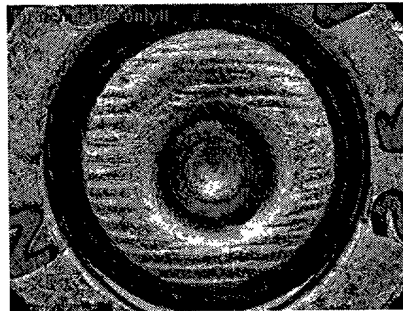


FIGURE 1a

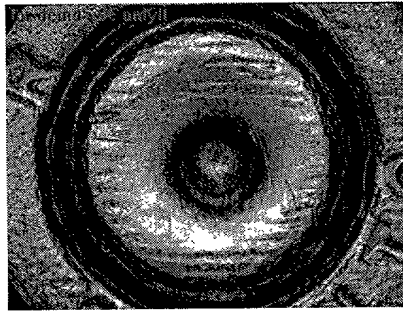


Figure 1b



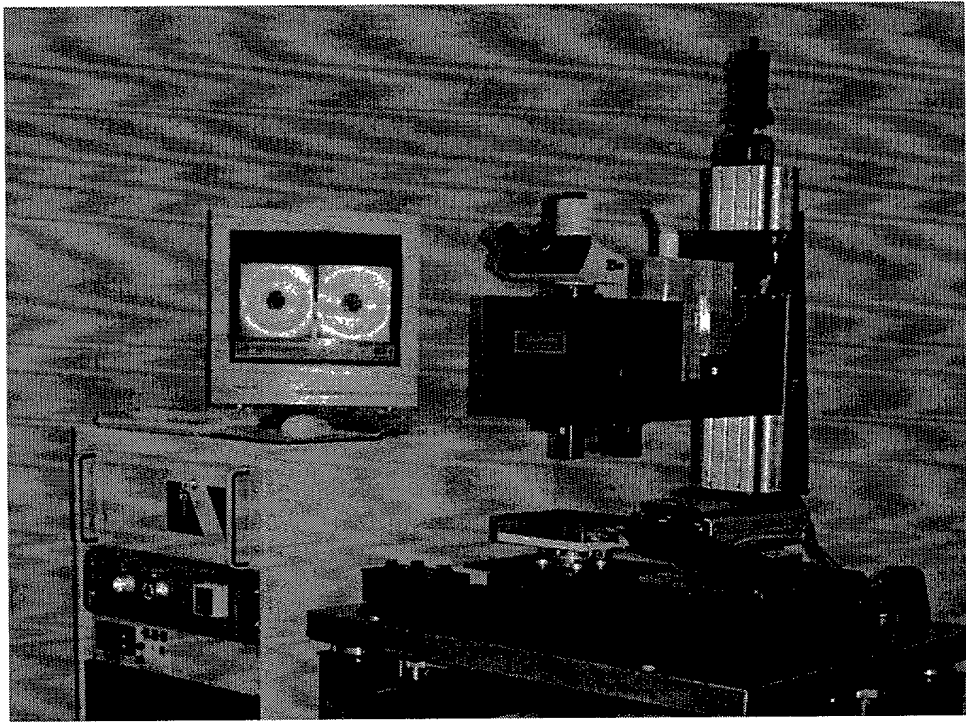


FIGURE 2

\_\_\_\_\_



"

ENCLOSURE

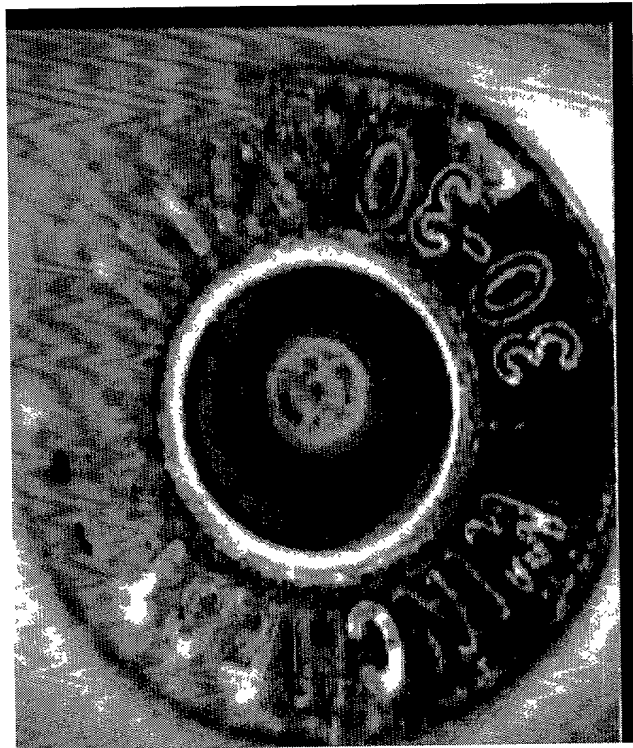


FIGURE 4

SECRET

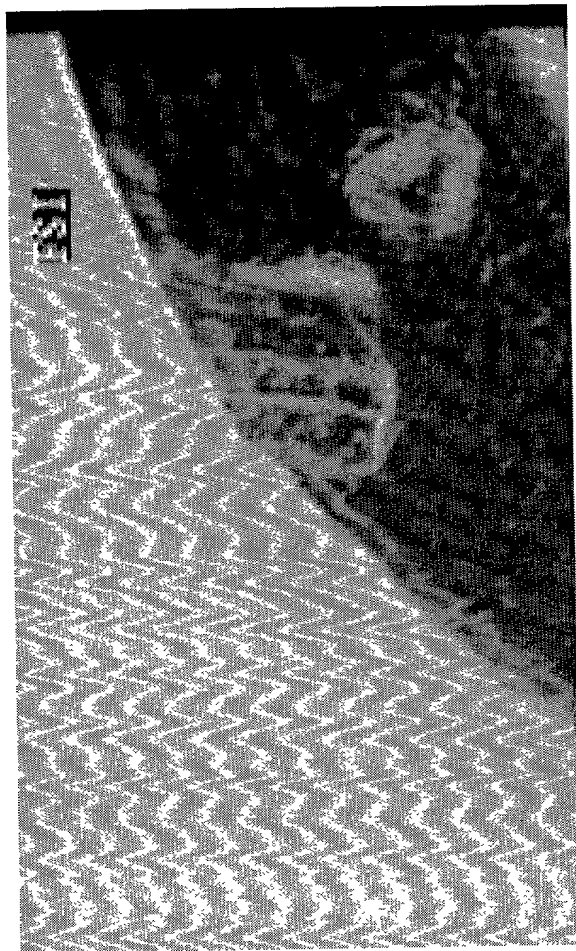


FIGURE 5

**Table 1.** Demographic characteristics of study population

|                         | N (%)      |
|-------------------------|------------|
| Age group (years)       |            |
| <60                     | 79 (8.2)   |
| 60-69                   | 100 (10.5) |
| 70-79                   | 100 (10.5) |
| ≥80                     | 100 (10.5) |
| Total                   | 279 (29.2) |
| Gender                  |            |
| Male                    | 150 (15.7) |
| Female                  | 129 (13.6) |
| Total                   | 279 (29.2) |
| Ethnicity               |            |
| Chinese                 | 100 (10.5) |
| Malay                   | 100 (10.5) |
| Indian                  | 100 (10.5) |
| Others                  | 79 (8.2)   |
| Total                   | 379 (39.7) |
| Marital status          |            |
| Married                 | 100 (10.5) |
| Single                  | 100 (10.5) |
| Widowed                 | 100 (10.5) |
| Divorced                | 79 (8.2)   |
| Total                   | 379 (39.7) |
| Education level         |            |
| Primary school or below | 100 (10.5) |
| Secondary school        | 100 (10.5) |
| Tertiary school         | 100 (10.5) |
| Total                   | 300 (31.5) |
| Religion                |            |
| Buddhist                | 100 (10.5) |
| Hindu                   | 100 (10.5) |
| Muslim                  | 100 (10.5) |
| Catholic                | 79 (8.2)   |
| Others                  | 79 (8.2)   |
| Total                   | 468 (49.1) |



FIGURE 6

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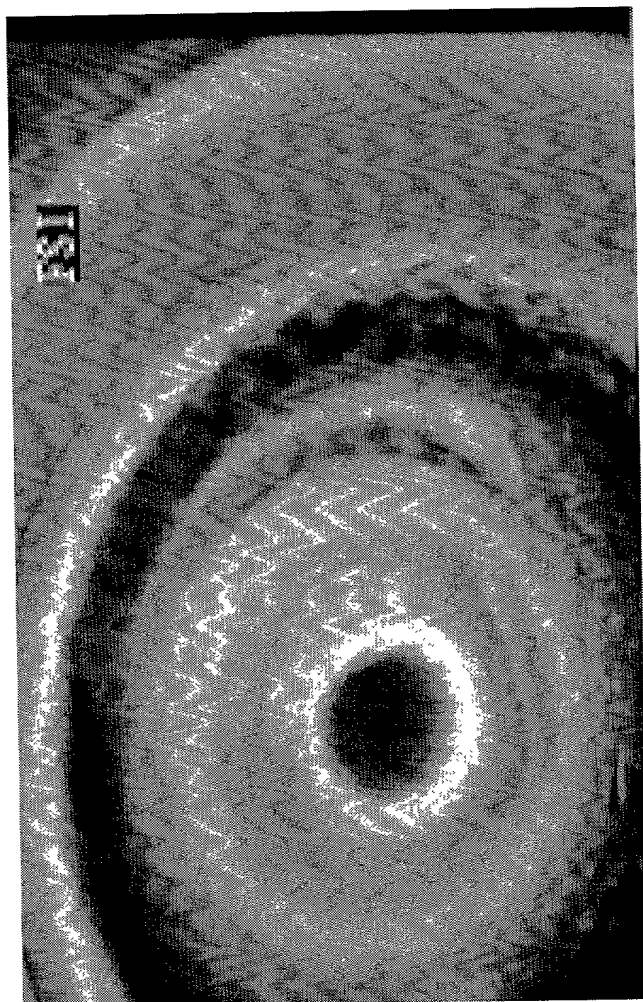


FIGURE 7

SECRET

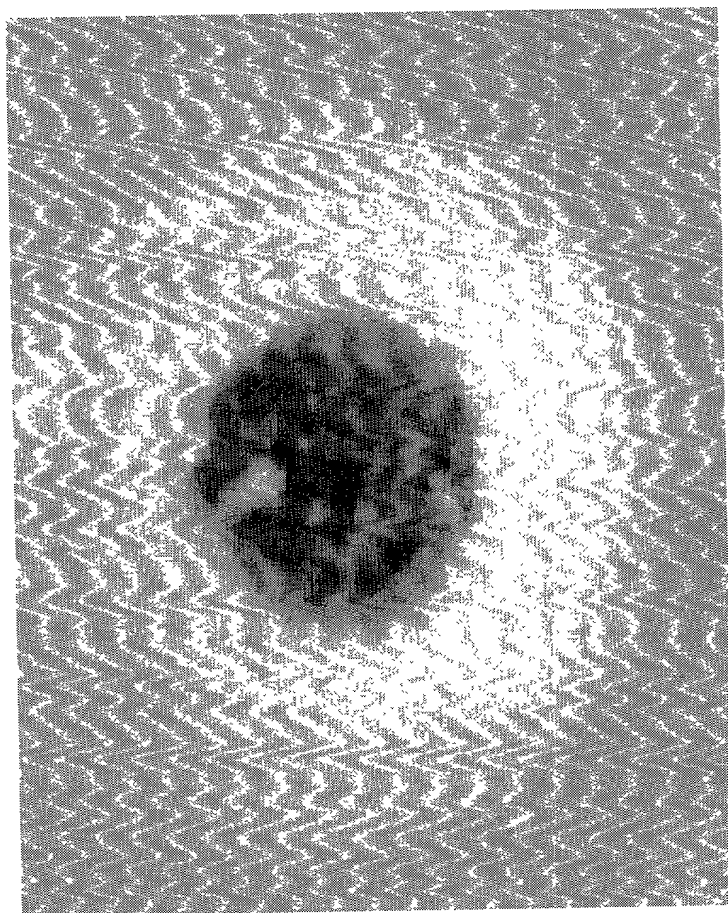


FIGURE 8



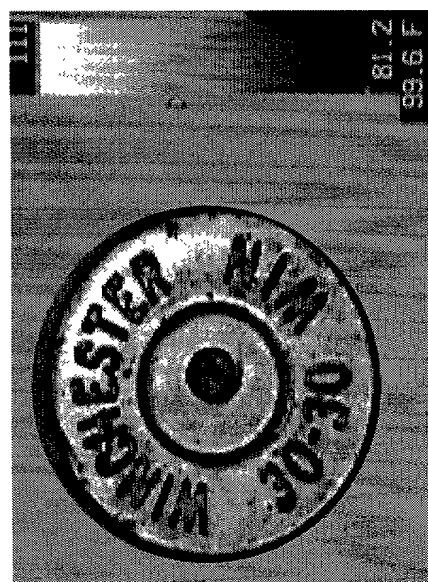
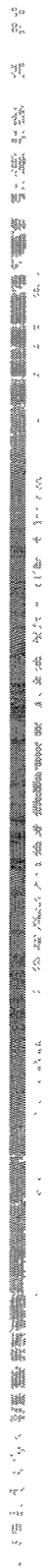


FIGURE 10

[illegible]

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| 赵红梅 | 女  | 41 | 江苏  | 医生  | 大专   | 良好   | 已婚   | 1子1女 |    |
| 孙为民 | 男  | 35 | 浙江  | 工程师 | 本科   | 良好   | 已婚   | 1子1女 |    |
| 周丽娟 | 女  | 29 | 湖北  | 护士  | 中专   | 良好   | 已婚   | 1子1女 |    |
| 吴大伟 | 男  | 48 | 四川  | 干部  | 高中   | 良好   | 已婚   | 2子1女 |    |
| 郑晓芳 | 女  | 33 | 广东  | 会计  | 大专   | 良好   | 已婚   | 1子1女 |    |
| 陈永年 | 男  | 55 | 湖南  | 工人  | 初中   | 一般   | 已婚   | 3子2女 |    |
| 刘静怡 | 女  | 27 | 福建  | 教师  | 本科   | 良好   | 已婚   | 1子1女 |    |
| 徐志远 | 男  | 42 | 安徽  | 农民  | 小学   | 一般   | 已婚   | 2子1女 |    |
| 马海燕 | 女  | 36 | 江西  | 医生  | 大专   | 良好   | 已婚   | 1子1女 |    |
| 郭为民 | 男  | 50 | 山西  | 干部  | 高中   | 良好   | 已婚   | 2子1女 |    |
| 黄丽娟 | 女  | 31 | 广西  | 护士  | 中专   | 良好   | 已婚   | 1子1女 |    |
| 朱大伟 | 男  | 44 | 云南  | 工人  | 初中   | 一般   | 已婚   | 3子2女 |    |
| 周晓芳 | 女  | 28 | 贵州  | 教师  | 本科   | 良好   | 已婚   | 1子1女 |    |
| 吴永年 | 男  | 53 | 海南  | 农民  | 小学   | 一般   | 已婚   | 2子1女 |    |
| 刘静怡 | 女  | 26 | 宁夏  | 医生  | 大专   | 良好   | 已婚   | 1子1女 |    |
| 徐志远 | 男  | 43 | 内蒙古 | 干部  | 高中   | 良好   | 已婚   | 2子1女 |    |
| 马海燕 | 女  | 37 | 新疆  | 护士  | 中专   | 良好   | 已婚   | 1子1女 |    |
| 郭为民 | 男  | 49 | 甘肃  | 工人  | 初中   | 一般   | 已婚   | 3子2女 |    |
| 黄丽娟 | 女  | 32 | 青海  | 教师  | 本科   | 良好   | 已婚   | 1子1女 |    |
| 朱大伟 | 男  | 46 | 陕西  | 农民  | 小学   | 一般   | 已婚   | 2子1女 |    |
| 周晓芳 | 女  | 29 | 宁夏  | 医生  | 大专   | 良好   | 已婚   | 1子1女 |    |
| 吴永年 | 男  | 51 | 甘肃  | 干部  | 高中   | 良好   | 已婚   | 2子1女 |    |
| 刘静怡 | 女  | 27 | 宁夏  | 护士  | 中专   | 良好   | 已婚   | 1子1女 |    |
| 徐志远 | 男  | 45 | 宁夏  | 工人  | 初中   | 一般   | 已婚   | 3子2女 |    |
| 马海燕 | 女  | 38 | 宁夏  | 教师  | 本科   | 良好   | 已婚   | 1子1女 |    |
| 郭为民 | 男  | 54 | 宁夏  | 农民  | 小学   | 一般   | 已婚   | 2子1女 |    |
| 黄丽娟 | 女  | 33 | 宁夏  | 医生  | 大专   | 良好   | 已婚   | 1子1女 |    |
| 朱大伟 | 男  | 47 | 宁夏  | 干部  | 高中   | 良好   | 已婚   | 2子1女 |    |
| 周晓芳 | 女  | 30 | 宁夏  | 护士  | 中专   | 良好   | 已婚   | 1子1女 |    |
| 吴永年 | 男  | 52 | 宁夏  | 工人  | 初中   | 一般   | 已婚   | 3子2女 |    |
| 刘静怡 | 女  | 28 | 宁夏  | 教师  | 本科   | 良好   | 已婚   | 1子1女 |    |
| 徐志远 | 男  | 48 | 宁夏  | 农民  | 小学   | 一般   | 已婚   | 2子1女 |    |
| 马海燕 | 女  | 39 | 宁夏  | 医生  | 大专   | 良好   | 已婚   | 1子1女 |    |
| 郭为民 | 男  | 56 | 宁夏  | 干部  | 高中   | 良好   | 已婚   | 2子1女 |    |
| 黄丽娟 | 女  | 34 | 宁夏  | 护士  | 中专   | 良好   | 已婚   | 1子1女 |    |
| 朱大伟 | 男  | 49 | 宁夏  | 工人  | 初中   | 一般   | 已婚   | 3子2女 |    |
| 周晓芳 | 女  | 31 | 宁夏  | 教师  | 本科   | 良好   | 已婚   | 1子1女 |    |
| 吴永年 | 男  | 53 | 宁夏  | 农民  | 小学   | 一般   | 已婚   | 2子1女 |    |
| 刘静怡 | 女  | 29 | 宁夏  | 医生  | 大专   | 良好   | 已婚   | 1子1女 |    |
| 徐志远 | 男  | 46 | 宁夏  | 干部  | 高中   | 良好   | 已婚   | 2子1女 |    |
| 马海燕 | 女  | 40 | 宁夏  | 护士  | 中专   | 良好   | 已婚   | 1子1女 |    |
| 郭为民 | 男  | 57 | 宁夏  | 工人  | 初中   | 一般   | 已婚   | 3子2女 |    |
| 黄丽娟 | 女  | 35 | 宁夏  | 教师  | 本科   | 良好   | 已婚   | 1子1女 |    |
| 朱大伟 | 男  | 50 | 宁夏  | 农民  | 小学   | 一般   | 已婚   | 2子1女 |    |
| 周晓芳 | 女  | 32 | 宁夏  | 医生  | 大专   | 良好   | 已婚   | 1子1女 |    |
| 吴永年 | 男  | 54 | 宁夏  | 干部  | 高中   | 良好   | 已婚   | 2子1女 |    |
| 刘静怡 | 女  | 30 | 宁夏  | 护士  | 中专   |      |      |      |    |

FIGURE 13

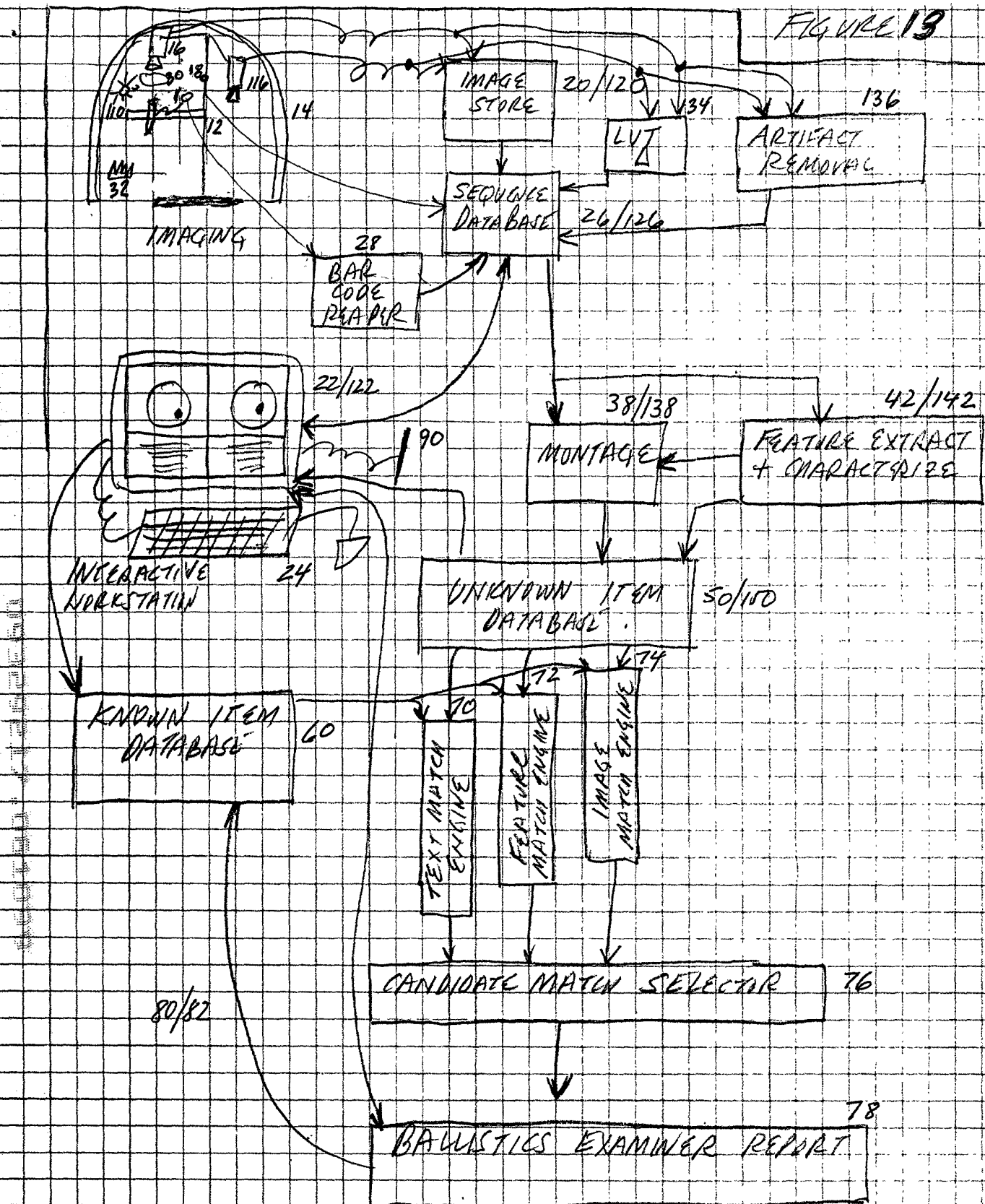
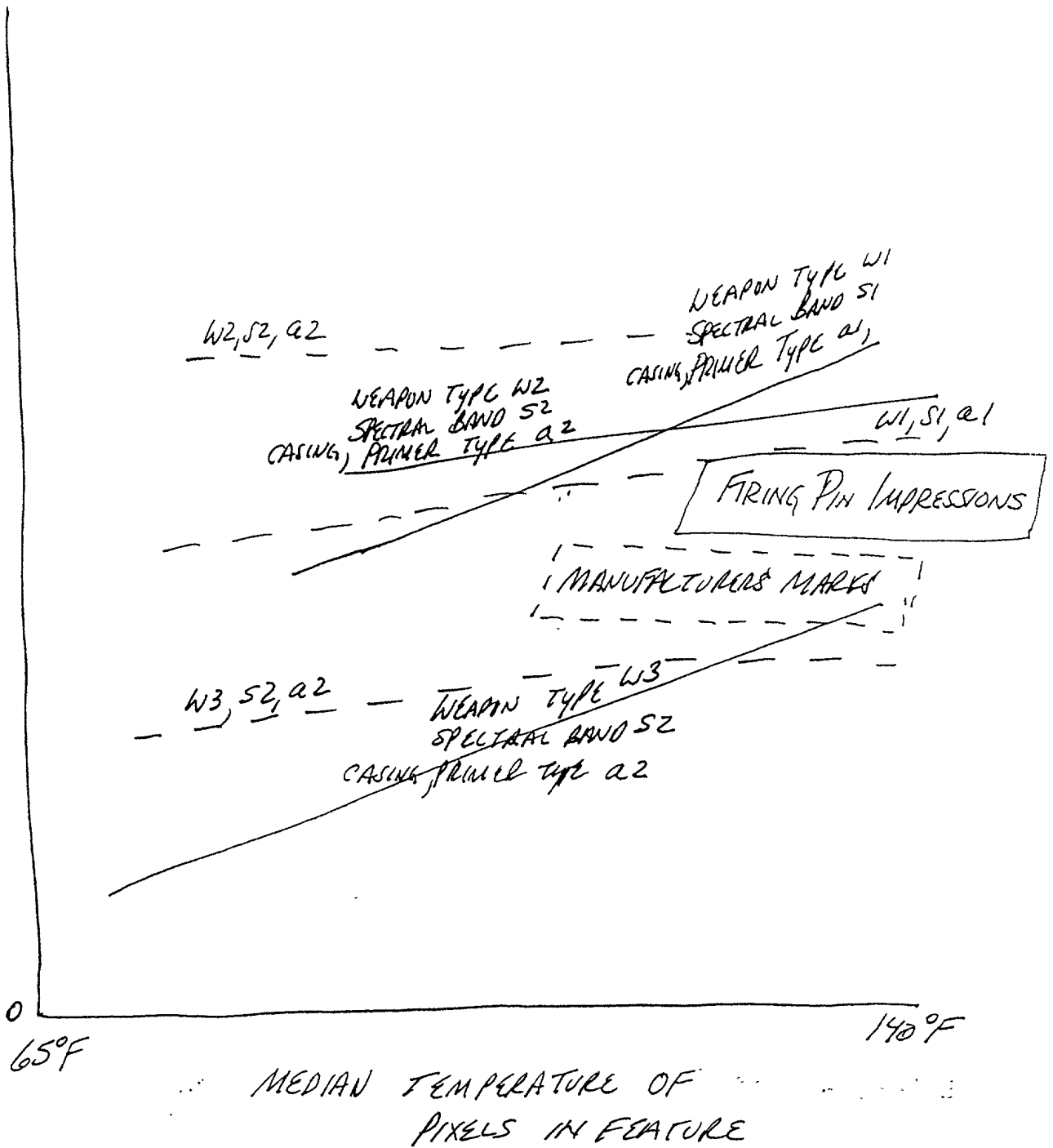


FIGURE 14

NUMBER OF PIXELS IN FEATURE



**DECLARATION FOR  
UTILITY PATENT APPLICATION**

As the below-named inventor, I hereby declare that:

My residence address and citizenship are as stated below next to my name.

I BELIEVE I THE ORIGINAL, FIRST AND SOLE INVENTOR OF THE SUBJECT MATTER WHICH IS CLAIMED AND FOR WHICH A PATENT IS SOUGHT ON THE INVENTION ENTITLED:

METHOD AND APPARATUS FOR ALIGNMENT, COMPARISON & IDENTIFICATION OF  
CHARACTERISTIC TOOL MARKS, INCLUDING BALLISTIC SIGNATURES

the specification of which

☒ [X]

is attached hereto;

☐ [ ]

was filed on \_\_\_\_ as Application Serial No. \_

and was amended on \_\_\_\_\_;

I HAVE REVIEWED AND UNDERSTAND THE CONTENTS OF THE ABOVE-IDENTIFIED SPECIFICATION, INCLUDING THE CLAIMS, AS AMENDED BY ANY AMENDMENT REFERRED TO ABOVE;

I ACKNOWLEDGE THE DUTY TO DISCLOSE TO THE OFFICE ALL INFORMATION KNOWN TO BE MATERIAL TO PATENTABILITY AS DEFINED IN TITLE 37, CODE OF FEDERAL REGULATIONS, Sec. 1.56 (as amended effective March 16, 1992);

I do not know and do not believe the said invention was even known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to said application; that said invention was not in public use or on sale in the United States of America more than one year prior to said application; that said invention has not been patented or made the subject of an inventor's certificate issued before the date of said application in any country foreign to the United States of America on any application filed by me or my legal representatives or assigns more than twelve months prior to said application;

I hereby claim foreign priority benefits under Title 35, United States Code Sec. 119 and/or Sec. 365 of any foreign applications(s) for patent or inventor's certificate as indicated below and have also identified below any foreign application for patent or inventor's certificate on this invention having a filing date before that of the application(s) on which priority is claimed:

Address all correspondence to:

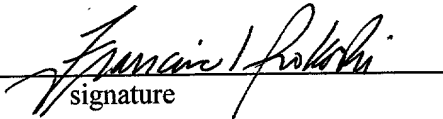
Dr. Francine Prokoski, POB 7025, Fairfax Station, Virginia 22039 USA

Address all telephone calls to:

703 493 9300, fax 703 690 7435, internet mikos@gte.net

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

**FRANCINE J. PROKOSKI**  
full name of sole inventor

  
signature

8 June 1999  
date

**POB 7025 Fairfax Station, VA 22039, USA**  
residence

**USA**  
citizenship

660150-1266660